

Sexual Reproduction In Flowering Plants

* Diversity in structures of
 inflorescences
 flowers
 floral parts
 shows amazing range of adaptation to ensure End products of Sexual Reproduction
 seeds
 fruits
 which are

Seat of sexual reproduction

FLOWER - A FASCINATING ORGAN OF ANGIOSPERM

* Flowers are object of

aesthetic value
 ornamental
 social
 religious
 cultural

they have been used as a symbol for conveying human feelings

love
 affection
 happiness
 grief
 mourning

* To biologist, Flowers are

morphological marvels
 sites of sexual reproduction
 embryological marvels

PRE - FERTILISATION : STRUCTURES & EVENTS

* Much before the actual flower is seen on a plant

decision that the plant is going to flower has taken place.

development
 differentiation
 of Floral primordium

which lead to

are initiated

hormonal changes

structural changes

develop
 different
 parts

male
 rep. struct.

female
 reprod.
 structure

flowers

Inflorescence are formed

then

Floral Bud

which bear

Stamen, Microsporangium & Pollen Grain

2 parts

Filament

long
 slender

Anther

generally
 bilobed

* Proximal end of filament attached

thalamus

to

Petal of this flower

* 1) Number
 2) Length
 of stamens
 Variable in flowers of different species.

Typical angiosperm anther → Bilobed ^{each lobe having} 2 theca (ditheous)

Bilobed nature $\xrightarrow{\text{very distinct in}}$ Transverse section of anther

Longitudinal groove runs lengthwise

To separate theca

Four sided structure (TETRAGONAL) consisting 4 microsporangia located at corners

Run all the way (all the length of anther) longitudinally & packed with pollen grains

Pollen sacs develop further & become

2 in each lobe

STRUCTURE OF MICROSPORANGIUM

* In a transverse section microsporangium → Nearly circular in outline

help in protection

outer 3

epidermis

endothecium

middle layer

4 wall layers

Surrounded by

Tapetum

Cells of tapetum are

thick cytoplasm

polyploid (more than one nucleus)

dehiscence of anther to release pollen grains

nourishes developing pollen grain

* When anther is young → group of

compactly arranged

homogeneous cells

called

centre of each microsporangium

occupies

Sporogenous tissue

MICROSPOROGENESIS

Cells of sporogenous tissue undergo meiotic division to form Microspore tetrad

each cell of sporogenous tissue capable of giving rise to microspore tetrad

each one is

potential pollen OR MMC (microspore mother cell)

microsporangium

Inside each microsporangium

several X1000s microspores/pollen grains

released with dehiscence of anther

4 microsporangia → X4000 pollen grains

Pollen grain

develop into

microsporangium

microspores

as they are formed

arranged in four cluster of cells (microspore tetrad)

As anther

① mature & ② dehydrate

Microspore dissociate from each other

Pollen Grain : Represent the male gametophyte.

Hibiscus anthers opened → yellowish pollen grains

- * Different species of pollen grains have different
 - sizes
 - shape
 - colours
 - design
- * Pollen grain has
 - generally spherical
 - 25-30 μ m diameter
 - Prominent 2-layered wall

Exine

- Hard, Outer
- Made of : Sporopollenin
 - most, resistant organic material
 - can withstand
 - high temp.
 - strong acids alkali
 - can't be degraded by any enzyme
- This layer has prominent apertures called germ pores
 - Sporopollenin absent here
- Pollen grains can be well preserved bcz of Sporopollenin
- Exine exhibits fascinating array of patterns designs

Intine

- Inner
- Thin
- Continuous
- Made of cellulose pectin

• Cytoplasm of pollen grain → surrounded by → Plasma membrane

• When pollen grain mature it contains 2 cells

Vegetative cell

- Bigger
- Abundant food reserve
- Large Irregular shaped → Nucleus

Generative cell

- Small
- Floats in Cytoplasm of vegetative cell.
- Spindle shaped cell
- nucleus

* Pollen grains shed at 2 celled stage → in 60% of angiosperm

* " " shed at 3 celled stage → rest 40% of " .

1 generative male gamete | 1 vegetative male gamete

- * Pollen grains of many species cause severe allergies, bronchial affections, asthma, bronchitis, chronic affections/respiratory disorders leading to
- * Cause pollen allergy, ubiquitous occurrence → Parthenium / Carrot grass → come into India as contaminant → Imported Wheat with
- * Pollen grains → rich in nutrients
- * Fashion in recent years to use Pollen tablets as food supplement
- * In western countries → large no. of Pollen products in form of tablets, syrups → available in market
- * Pollen consumption has been claimed to ↑ performance of athletes, race horses

- * Once they shed they have to land on stigma before they lose their viability if they have to bring fertilization

Period for which pollen grain remain viable
↓
highly variable

depends on
Humidity prevalent
temperature

Rice (cereals) Wheat
↓
viable for 30 min

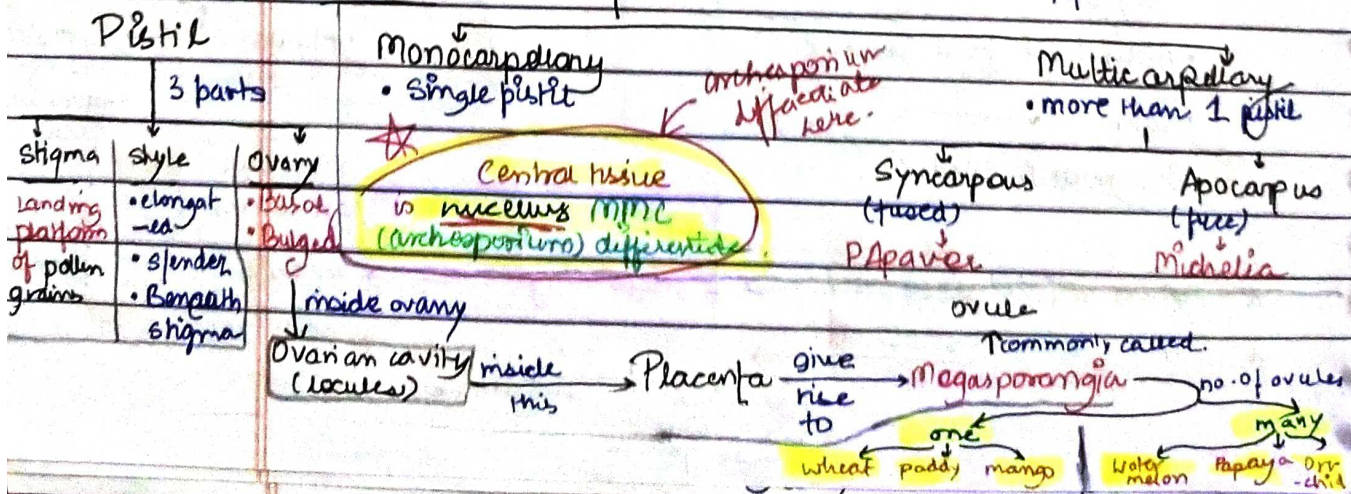
Rosaceae
Leguminosae
Solanaceae
↓
viable for months

- * Possible to store pollen grains of large no. of species for years in liquid N_2 ($-196^\circ C$)

Such pollen can be used as
Pollen Banks (similar to seed banks)
in Crop breeding programmes

PISTIL, MEGASPORANGIUM (OVULE) & EMB

GYO SAC Gynoecium represents Female Reproductive Part of flower.



The Megasporangium (OVULE) → Typical angiosperm ovule.
 • Ovule (small structure) attached to Placenta by means of stalk - Funicle → anatropous

• Ovule fuses with body → Funicle * Junction b/w ovule & funicle } → Hilum

* Each Ovule has one OR two } Protective envelope called Integuments → entire nucellus

Opposite end of micropyle → Chalaza → Basal part of ovule
Micropyle (small opening) ← except at the tip

* Enclosed within integuments a mass of cells → Nucellus cells of nucellus have abundant food reserves
 on Ovule generally has single embryo sac
megaspore ← formed from
 located inside this is Embryo sac (Female gametophyte)

MEGASPOROGENESIS → Process of formation of Megaspore from MMC.

• Ovules generally differentiate a Megaspore mother cell (MMC) (in micropylar region) of nucellus → Large cell dense cytoplasm prominent nucleus

• MMC undergoes meiosis → 4 megaspores

FEMALE GAMETOPHYTE

(Other 3) degenerate Functional megaspore ← one of the megaspore In majority of flowering plants

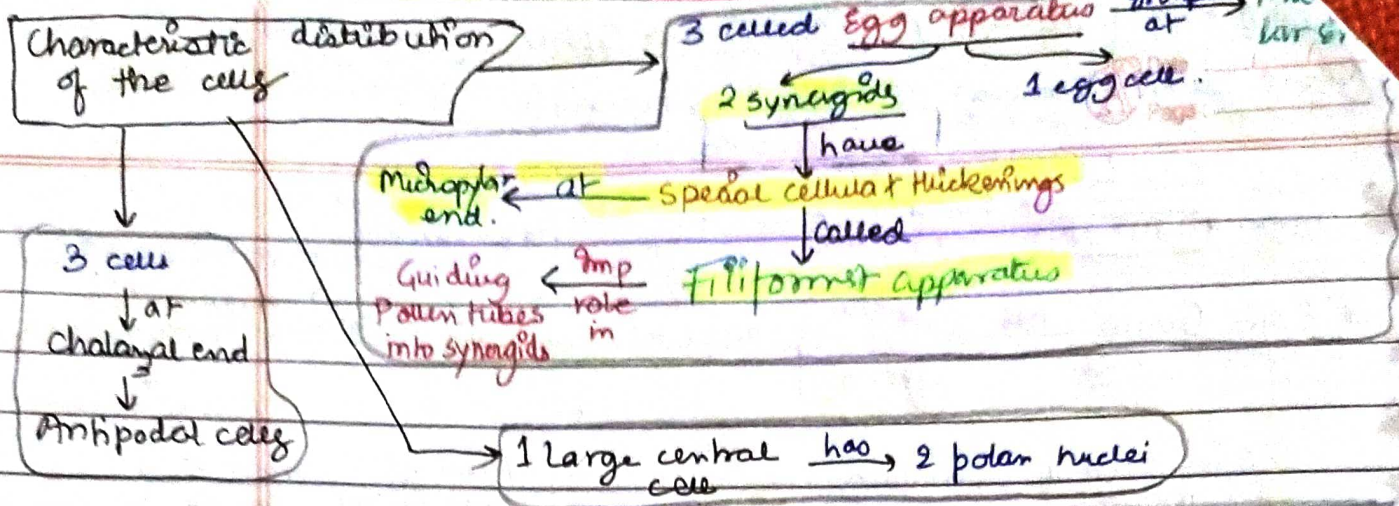
develops into Female Gametophyte (embryo sac)

Monosporic - method of formation of a embryo sac from single megaspore.

Nucleus of megaspore divides mitotically to form 2 nuclei which move to opposite poles
 simply free nuclear not followed immediately by cell wall formation

2-nucleate embryo sac → forming 8 nucleated, 7 celled
 4 nucleate ← 2 more sequential nuclear mitotic division to form
 4 nucleate stage

after this stage cell walls are laid down leading to form of Typical Female Gametophyte (Embryo sac)
 cells organised into 6 nuclei (surrounded by cell walls) & 2 nuclei (not surrounded by cell walls) → POLAR NUCLEI
 situated below egg apparatus in large central cell.



POLLINATION Both gametes - non-motile. *(Have to be brought together for fertilisation)*

mechanism to achieve this

- Pollination - Transfer of pollen grains (shed from anther) to the stigma of pistil
- Flowering plants have evolved amazing array of adaptations to achieve pollination. *(make use of external agents to achieve)*

KINDS OF POLLINATION (Depending on source of pollen)

| Autogamy | Geitonogamy | Xenogamy |
|--|--|---|
| <ul style="list-style-type: none"> • Achieved within same flower • Transfer of pollen grain from stigma to anther (of same flower) • In normal flower which opens, anther & stigma enposes → complete autogamy is rare. | <ul style="list-style-type: none"> Transfer of pollen from anther to stigma of another flower on same plant | <ul style="list-style-type: none"> Transfer of pollen grains from anther to stigma of different plant |
| <ul style="list-style-type: none"> ① Synchronisation required in pollen release & stigma receptivity ② Anther & stigma should lie close for self pollination to occur | <ul style="list-style-type: none"> Functionally: Cross pollination (involving pollinating agent) Genetically: Autogamy (bcz of same plant) | <ul style="list-style-type: none"> Only pollination, which brings genetically different type of pollen grain to stigma |

Eg. → Viola (common pansy), *Orchids*, *Commelina*

produce 2 types of flowers

Chasmogamous - exposed anther & stigma

Cleistogamous - do not open

Cleistogamous flowers → invariably autogamous → as there are no chance of cross pollen landing on stigma

produce assured set seed

* When anthers dehisce in flower bud pollen grain comes in contact with stigma to effect pollination

even in absence of pollinators

Agents of Pollination →

Plant uses

2 types of agents

more common
Wind

Abiotic factor

used by small proportion of plants

Water

Used by majority of plants

Biotic Factor

Animals

Pollen grains coming in contact with stigma is a chance factor.

to compensate for uncertainty & associated loss of pollen

Flowers produce

Enormous amt. of pollen when compared to the no. of ovules available for pollination.

By WIND

→ more common amongst abiotic pollination

requires
POLLEN GRAIN → light
→ non-sticky {so they can be transported by wind currents}

often possess

Well exposed stamens

so that Pollens are easily dispersed
Wind currents → into

Large Feathery stigma

to easily trap air-borne pollen grains.

wind pollinated

plants usually have

Single ovule in each ovary

Numerous flowers packed into inflorescence

Eg. Corn cob → (Tassels) are style stigma → waving in wind
pollens → to trap

Wind pollination common in Grasses

By WATER

Quite Rare in flowering plants

Limited to about

30 genera mostly Monocots

Against this recall Water is regular mode of transport
their distribution is limited
because of need of water for transport of male gametes
fertilization
algae
Bryophytes
Pteridophytes
in male gametes for

★ WATER POLLINATED PLANTS

Fresh water → Vallisneria
Hydrilla

marine → Sea grasses (as Zostera)

* Not all aquatic plants - water pollinated

* In majority of Aquatic plants $\left\{ \begin{array}{l} \text{Water hyacinth} \\ \text{Water Lily} \end{array} \right\} \rightarrow \text{Flowers}$
Insects \rightarrow then pollinated by \rightarrow above sea level of water \rightarrow emerge

VALLISNERIA \rightarrow Flowers reach \rightarrow Surface of water by long stalk
 \rightarrow male flowers / pollen grains released on surface of water
Stigma \leftarrow some of them reach \leftarrow Water currents \leftarrow by \leftarrow carried passively

SEA GRASSES \rightarrow ♀ flowers remain submerged in water
 \rightarrow Pollen grains released inside water
 \rightarrow long ribbon like \rightarrow carried passively inside water
Some reach stigma \rightarrow cause pollination

* In most of the Water pollinated species \rightarrow Pollen grains protected from \rightarrow Wetting by mucilaginous covering

* Both $\left\{ \begin{array}{l} \text{Wind pollinated plants} \\ \text{Water pollinated plants} \end{array} \right\} \rightarrow \left\{ \begin{array}{l} \text{colourful} \\ \text{produce nectar} \end{array} \right.$

ANIMAL POLLINATED \rightarrow used by majority of flowering plants

Example \rightarrow Bees Butterflies Flies Beetles wasps Ants moths Birds Bats
common pollinating animals \rightarrow Sunbirds humming birds

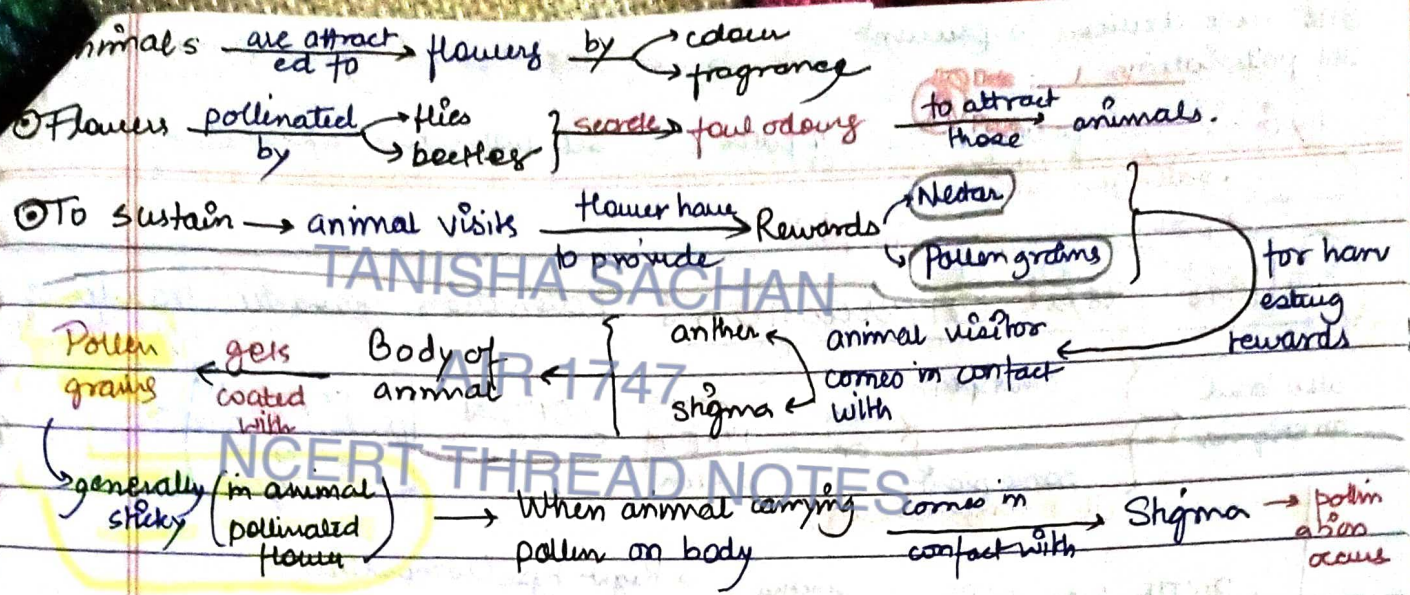
* Among animals \rightarrow Insects (Particularly Bees) \rightarrow Dominant Biotic pollinating agents

* Even large animals have been reported as pollinators \rightarrow primates \rightarrow lemurs
 \rightarrow arboreal rodents (tree dwelling)
 \rightarrow Reptiles \rightarrow gecko lizard
 \rightarrow garden lizard

Often \rightarrow Flowers of animal pollinated plants specifically adapted for a particular species of animal

* Majority of insect pollinated flowers \rightarrow large \rightarrow colourful \rightarrow fragrant \rightarrow Rich in nectar

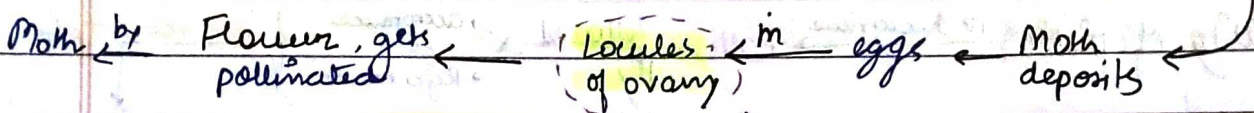
* When flowers are small \rightarrow a no. of flowers \rightarrow packed into inflorescence \rightarrow to make them conspicuous



- In some species \rightarrow Floral rewards $\xrightarrow[\text{are}]{}$ providing safe places to lay eggs

Example \rightarrow Tallest flower (*Amorpha*)
Flower - 6 ft tall

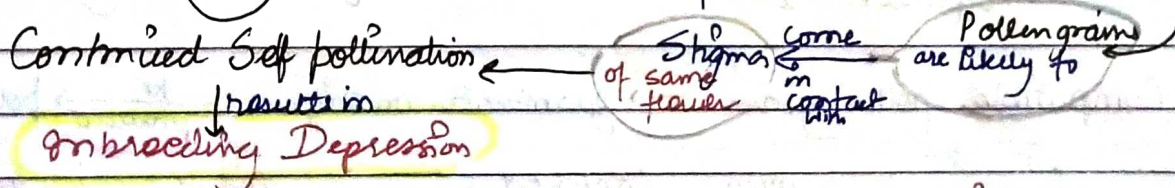
- Moth & Yucca \rightarrow both species cannot complete their life cycle without each other



Larvae of moth comes out of eggs \rightarrow as seeds start developing

* Many insects consume pollen & nectar without bringing pollination
(*Bombus affinis*)

Outbreeding Devices: Majority of flowering plants produce hermaphrodite flowers



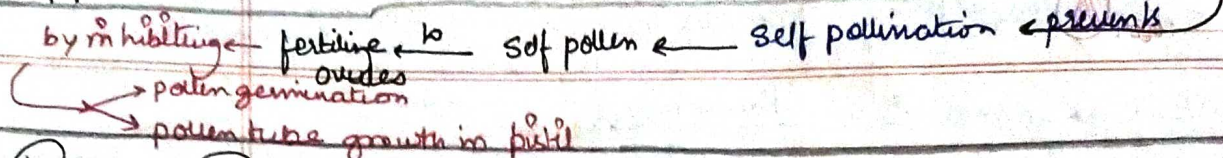
- * Flowering plants have developed many devices to discourage self pollination.

| In some species | In some other species | Prod. of unisexual flowers promote cross pollination |
|---|--|---|
| <p>Pollen release & Stigma receptivity</p> <p>Synchronized</p> <p>\downarrow</p> <p>Either pollen release before stigma becomes receptive or vice-versa</p> | <p>Anther & Stigma</p> <p>placed at different position</p> <p>\downarrow so that</p> <p>pollen cannot come in contact with stigma</p> | <p>Monocious - Castor, Maize</p> <p>prevents autogamy but not geitonogamy</p> |
| | | <p>Dioecy - Papaya</p> <p>σ^7 & ϕ flower on diff. plants. This cond. prevents both autogamy & geitonogamy</p> |

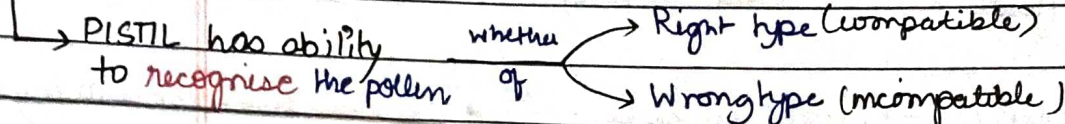
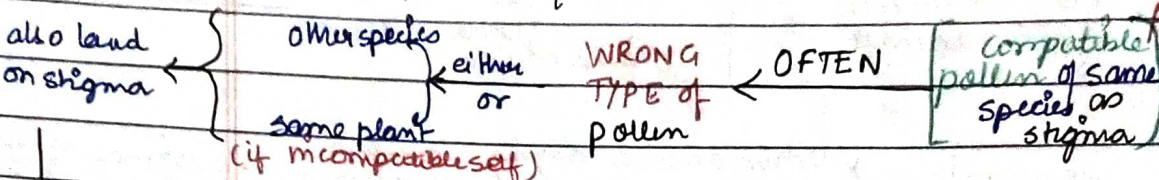
One more device to prevent self pollination

Self-incompatibility

Genetic mechanism



Pollen Pistil Interaction: Pollination ~~guarantee~~ transfer of right type of pollen



* If ✓ type pistil accepts pollen → promotes post pollination events leads to fertilization

* If X type pistil rejects pollen → by preventing pollen germination on stigma
→ prevents pollen tube growth in style.

Ability of pistil to recognise Pollen followed by acceptance or rejection is a result of

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Chemical components of pollen interacting with those of pistil

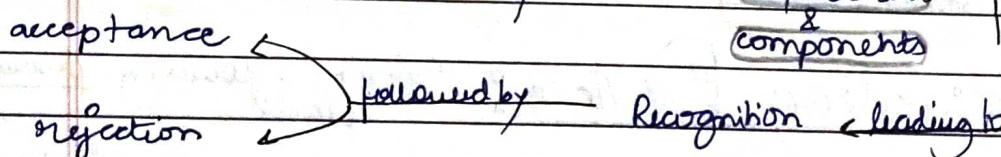
this dialogue is mediated by

Continuous dialogue b/w pollen grain & pistil

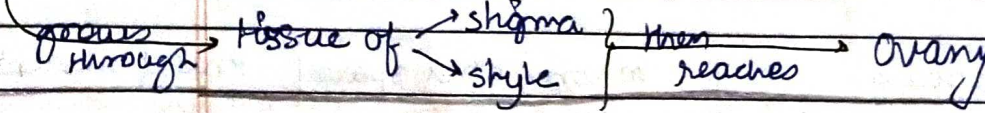
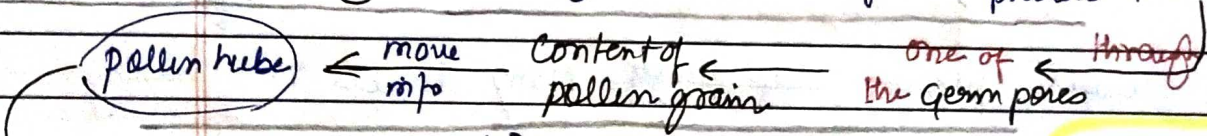
* In Recent years

→ Botanists have been able to identify some

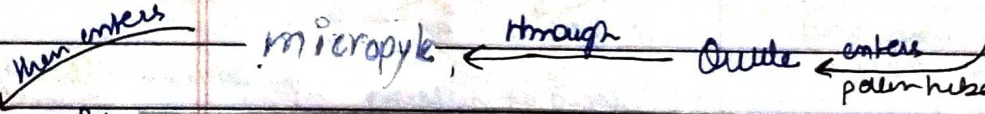
pollen & pistil interactions & components



* Compatible pollen grain → germinates on stigma → to produce pollen tube

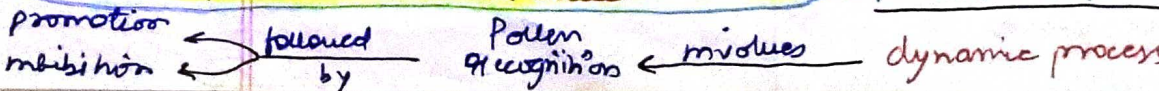
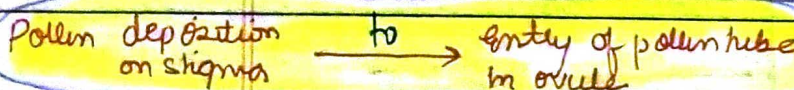


Generative cell divides into 2 male gametes during growth of pollen tube



Synergids through filiform apparatus

Studies show → Filiform apparatus at micropylar end guides entry of pollen tube



POLEN PISTIL INTERACTION

Knowledge gained in this area would lead to **Plant Breeder in manipulating pollen-pistil interaction**
 desired hybrids ← to get incompatible pollinations ← even in

* To study Pollen Germination → Dusting some pollen from
 pea chickpea Balsam Vinca Crocholaria
 10% sugar soln ← containing on a slide
 drop (a drop)
 After → 15-30 min observe slide under Low power lens of microscope
 Pollen tubes coming out of pollen grain ← You are likely to see

Breeder is interested in crossing different species & genera to combine desirable characters
 commercially superior varieties ← to produce

ARTIFICIAL HYBRIDISATION is one of the major approach of Crop improvement Programme
 in such crossing experiments

its imp to make sure Only desired pollen grains used for pollination

Stigma is protected from contamination (unwanted pollen) achieved by **Emasculation** & **Bagging**

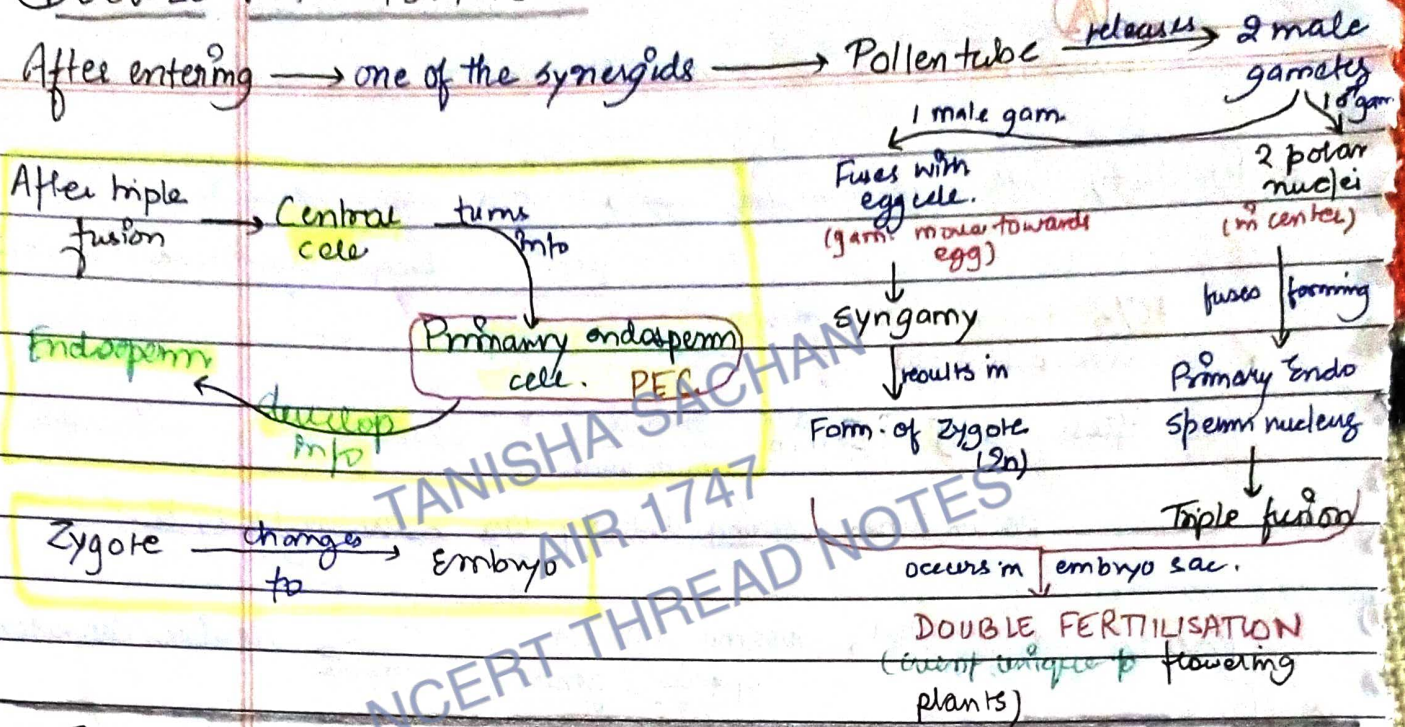
* If female parent bears bisexual flowers
 necessary Removal of anthers
 ① from flower bud
 ② (before anthers dehisce)
 using a forceps
EMASCULATION
 have to be covered by Emasculated flowers

Bag (of suitable size) made of: Butter paper to prevent contamination of stigma by unwanted pollen. This process → **BAGGING**

mature pollen is collected from ♂ parent
 dusted on stigma → Flowers **REBAGGED** → Fruits allowed to develop
 When stigma of bagged flower receptively attains

* If ♀ flower — unisexual → **Emasculation** → Female flowers bud are bagged before it opens
 Flowers rebagged ← (with desirable pollen) carried ← When stigma receptive

DOUBLE FERTILISATION



POST FERTILISATION: STRUCTURES & EVENTS

- Post fertilisation events:
 - endosperm development
 - embryo development
 - Maturation of ovules (s) → seed(s)
 - Ovary into fruit

ENDOSPERM

Endosperm development precedes → Embryo development.

PEC divides repeatedly forming triploid Endosperm ($3n$) tissue. cells of this tissue is filled with Reserve food materials.

In most common type of Endosperm development → PEN → nucleus of the developing embryo → used for successive nuclear division

Free-nuclear Endosperm → This stage is called Free nuclei → to give rise to

Subsequently cell wall formation occurs → endosperm becomes Cellular.

No. of free nuclei formed before cellularisation varies greatly

(Coconut water) from → Tender coconut free nuclear endosperm (X1000s of nuclei)

Surrounding white kernel → Cellular Endosperm

EMBRYO

develops at Microphyllar end of embryo sac where Zygote is situated

* Most zygotes divide only after certain amt. of endosperm formed.

developing embryo \leftarrow to \leftarrow to provide assured nutrition

ADAPTATION

* Though seeds differ greatly, early stages of embryo development (EMBRYOGENY) are similar in both

Monocotyledons

Dicotyledons

Zygote $\xrightarrow{\text{gives rise to}}$ Proembryo \rightarrow Globular shaped \rightarrow Heart shaped \rightarrow Mature Embryo

• Typical dicotyledonous embryo consists of embryonal axis & 2 cotyledons

• Portion of embryonal axis above level of cotyledons \rightarrow Epicotyl which terminates with Plumule (P.R) or Stem tip

• Cylindrical portion below level of cotyledons \rightarrow Hypocotyl terminates at its lower end in Radicle or Root tip

• Monocotyledonous embryo

possess only 1 cotyledon (scutellum)

① Radicle & Root cap \leftarrow At lower end of embryonal axis \leftarrow Lateral (concave side) of the embryonal axis \leftarrow situated towards

enclosed by undifferentiated sheath \downarrow called COLEORRHIZA

Root cap \leftarrow covered by

* Portion of embryonal axis above the level of attachment of scutellum \rightarrow Epicotyl

COLEOPTILE \leftarrow called structure Hollow Foliar \leftarrow enclosed in shoot apical & leaf primordia \leftarrow This has

SEED

\rightarrow Final product of Sexual Reproduction

\rightarrow Fertilized ovule

\rightarrow formed inside \rightarrow fruit

typically consists of seed coats, cotyledons & Embryonal axis

Cotyledons of embryo are thick & swollen \rightarrow due to storage of reserve food (as in LECULUM)

Perispermic seeds \rightarrow black pepper & beet

In some seeds \rightarrow remnants of nucellus persistent \rightarrow PERISPERM

Integuments of ovules $\xrightarrow{\text{harden as}}$ Tough protective \rightarrow Seed coat

micropyle $\xrightarrow{\text{remains as}}$ small \downarrow in seeds coat

* As seeds mature \rightarrow water content $\downarrow\downarrow\downarrow$

seeds \leftarrow into \leftarrow facilitates entry of O_2 (water)

relatively dry \leftarrow seeds become \leftarrow moisture \leftarrow 10-15% by mass

* General metabolic activity of embryo $\downarrow\downarrow$ embryo enters \rightarrow State of inactivity (Dormancy)

Seeds germinate \leftarrow available \leftarrow adequate moisture \leftarrow O_2 \leftarrow favourable cond. available \leftarrow suitable temp

Mature seeds may be

Non albuminous

Ex - albuminous

* NO residual endosperm as it is completely consumed during embryo development

Albuminous seeds

* Retain a part of endosperm.

(not completely consumed during embryo development)

Pea

Groundnut

wheat mango barley Castor

* Ovule $\xrightarrow{\text{matures into}}$ Seed

* Ovary $\xrightarrow{\text{develops into}}$ fruit

Fleshy fruits
Guava, Orange
mango

Simultaneously

* Wall of ovary $\xrightarrow{\text{develops into}}$ wall of fruit (Pericarp)

Dry fruits
Groundnut
Mustard

* Many fruits have evolved mechanism for seed dispersal

* In most plants \rightarrow by the time fruit develops from ovary

other floral parts degenerate & fall off

* In some species \rightarrow apple \rightarrow cashew \rightarrow strawberry

THALAMUS $\xrightarrow{\text{contributes to}}$ Fruit formation on

FALSE FRUITS \leftarrow such fruits

* Most fruits \rightarrow develop only from ovary \rightarrow called \rightarrow True fruits

* Few species → Fruits develop without fertilization
PARTHENO-CARPIC FRUITS
such fruits are

Banana.

* Parthenocarpy can be induced through Application of Growth Hormone & such fruits called seedless.

Seeds offer several advantages to Angiosperm

* Since → reproductive processes as pollination & fertilization are dependant on Water

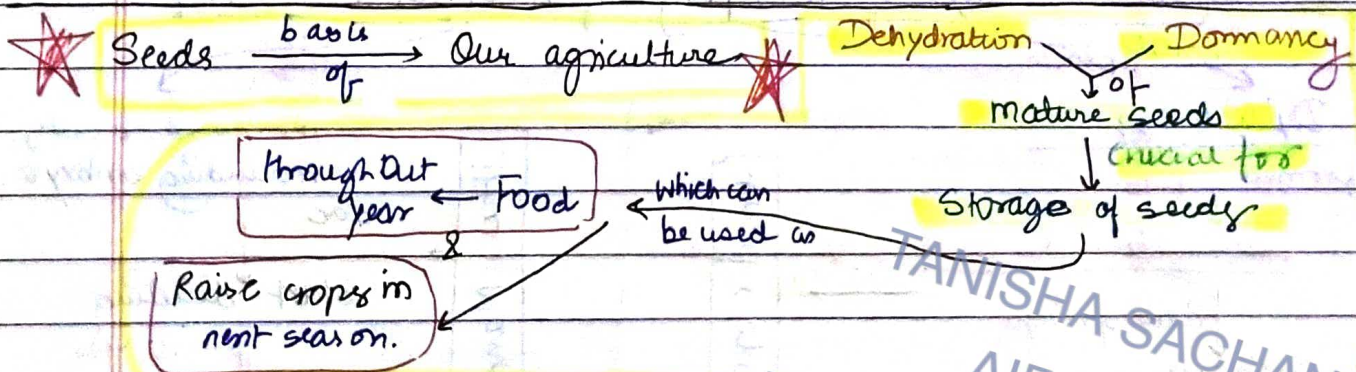
* Seeds have better adaptive strategies for dispersal to new habitats

colonise new areas to help the species

* As seedlings have sufficient food reserve seedlings are nourished
capable of photosynthesis until they are

* Hard seed coat provides protection to young embryos

* Embryo being product of Sexual Reproduction they generate new genetic combination
Variations leading to



* Viability periods differ greatly in different plants.

* In few species → seeds lose majority viability in few months

* Seeds of large no. of species live for several hundreds of years

* Some seeds → remain alive for hundreds of years

* Several records of very old yet viable seeds ?

Oldest is of → Lupine - *Lupinus Arcticus* ^{excavated from} Arctic Tundra
 10000 years of dormancy ← After a gap of ^{the seeds germinated & hatched}

Recent record is of → Date palm - *Phoenix dactylifera* ^{discovered from}
 Dead Sea. ← near King Herod's place ← at ^{Archaeological excavation}

* Orchid fruit → Each fruit contains 1000s of tiny seeds
 of *Orchid* ^{of} *Fructs of parasitic species* ^{similar in case of}

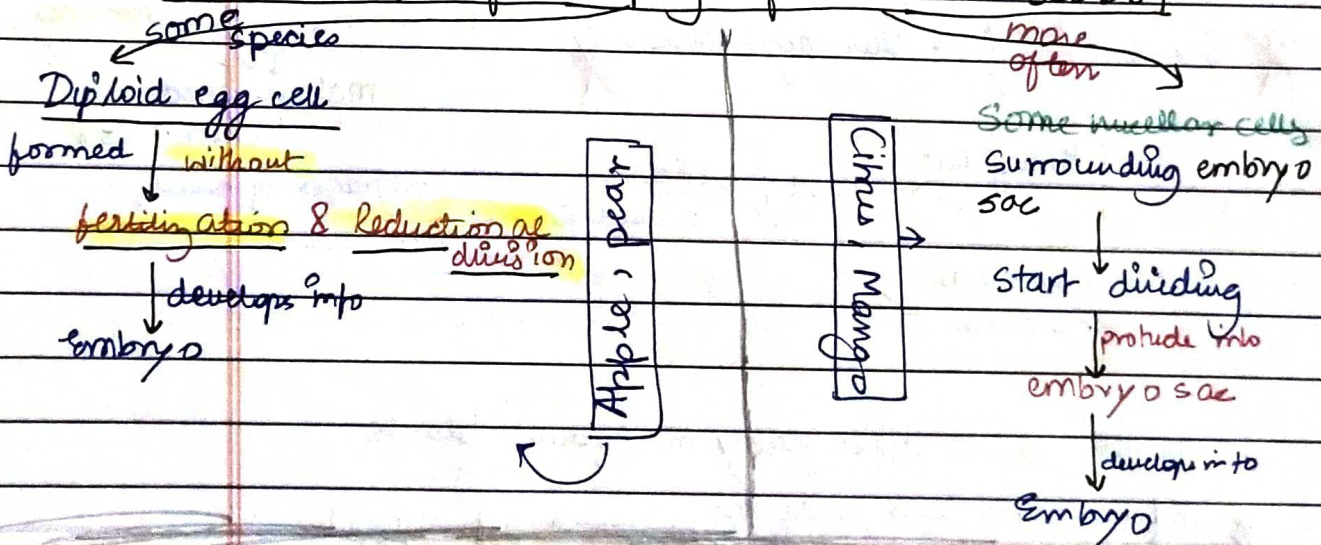
* Ficus tree produces billions of seeds

APOMIXIS & POLYEMBRYONY

Few flowering plants of some species of *Asteraceae* & *Grasses* ^{have evolved special mechanism}
APOMIXIS → fertilization without seeds to produce

form of → Asexual reprod. mimics Sexual Reproduction.

Several ways of developing of APOMICTIC SEEDS



In such species → Each ovule has many embryos.

POLYEMBRYONY ← referred to as

Apomixis have several advantage in → horticulture
 → agriculture

Hybrid varieties of several
 food
 vegetable crops
 being extensively cultivated

Cultivation of hybrid

has tremendously ↑↑ productivity

* One problem of hybrids is that hybrid seeds have

If seeds collected from hybrids are sown

to prod. every year.

plants in progeny will segregate & do not maintain hybrid characters.

Production of hybrid seeds

costly

expensive

for farmers

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~~Segregation of characters in hybrid progeny~~

But if hybrids are made into apomicts

Farmers can keep on using hybrid seeds to raise new crop after year

X does not have to buy hybrid seeds every year

born 2 inspire

Date ____ / ____ / ____

* Because of importance of apomixis in hybrid seeds industry

Active research is going on in many laboratories to understand around the world

Genetics of apomixis and transfer

hybrids varieties into apomictic genes

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